

# **Development of an Improved Method for Estimating Fugitive PM<sub>10</sub> Emissions from Windblown Dust from Agricultural Lands**

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## **ABSTRACT**

The standard methodology for estimating agricultural windblown dust, referred to as the wind erosion equation (WEQ), tends to produce inflated emission estimates for California. This occurs in part because it was developed in the Midwestern United States, and, therefore, does not take into account many of the environmental conditions and farm practices specific to California. The California Air Resources Board (ARB) staff has modified the WEQ to improve the emission estimate. This revision includes improved climatic factors, adjustments for the long-term effects of irrigation (cloddiness), as well as the short-term effects of irrigation on erodibility (surface wetness). Crop canopy coverage, postharvest soil cover, postharvest replanting to a different crop, as well as bare and border field regions are also accounted for in this revision. The monthly emissions profile now reflects variations in temperature, precipitation, irrigation, canopy coverage, postharvest soil cover, postharvest replanting to another crop, as well as wind. The result has been a downward revision in the annual emissions estimate of approximately 80 percent. The new annual and monthly emissions estimates better reflect the ambient monitoring source apportionment results, as well as California crop production patterns and climatic conditions.

## **INTRODUCTION**

California agricultural practices are different from much of the rest of the United States, and encourage approaches for estimating emissions that are in many respects quite different as well. California farmers grow a wide variety of crops, commonly irrigate, and, in most regions of the state, grow crops year-round. In addition, California exhibits subregional variations in climate due to terrain. In an effort to better reflect these attributes, the ARB staff has significantly modified the 1989 ARB agricultural windblown dust emissions methodology, <sup>1</sup> referred to here as the ARBWEQ1, used first to produce the inventory that was based on 1987 crop acreages.

The standard methodology for estimating the emission factor for windblown emissions from agricultural lands, which was used for the ARBWEQ1, is the wind erosion equation or WEQ. This method produces an annual estimate of emissions, which can also be adjusted to estimate monthly emissions. Since the implementation of the ARBWEQ1, the ARB staff has received many comments questioning the large windblown emission estimates it generates. In the case of California, the excessive emissions estimated by the ARBWEQ1 are in part due to the fact that the WEQ is based on Midwestern United States agricultural conditions and practices. The WEQ was developed by the United States Department of Agriculture - Agricultural Research Service (USDA-ARS) during the 1960's, for the estimation of wind erosion on agricultural land. <sup>2,3</sup> The United States Environmental Protection Agency (U.S. EPA) adapted the USDA-ARS methodology for use in estimating windblown particulate matter (PM) emissions from agricultural lands in 1974 (page 144 et seq. of EPA-450/3-74-037). <sup>4</sup> The U.S. EPA methodology was then adapted by ARB staff for the ARBWEQ1.

In the time since the ARBWEQ1 was produced, the USDA-ARS has been conducting ambitious programs to replace the WEQ with improved wind erosion prediction models. These USDA-ARS

programs include the development of the Revised Wind Erosion Equation (RWEQ) <sup>5</sup> and the Wind Erosion Prediction System (WEPS) <sup>6</sup> models. To date, these models have not proven feasible for use by the ARB, although certain portions of the RWEQ have been incorporated into the ARB methodology with this revision. This latest ARB methodology for estimating windblown agricultural emissions for particulate matter less than ten microns in size (PM10), described in this paper, will be referred to here as the ARBWEQ2.

## METHODOLOGY

The calculations for the ARBWEQ2 are only summarized here. Additional background, and details on the methodology are included in the actual methodology document <sup>7</sup> and the supplemental documentation <sup>8</sup> to this methodology, which are available on request from the ARB. Among the refinements incorporated into the ARBWEQ2 are: Improved annual and monthly climatic factors, irrigation effects, crop canopy, soil cover, replanting (multiple crops within an annual cycle), and estimates of bare and border region effects.

The acreages of agricultural crops used in the ARBWEQ2 are from the 1993 harvested acreage data provided to ARB staff by the California Department of Food and Agriculture (CDFA). <sup>9</sup> The ARBWEQ2 has been applied to nearly all of the crops in the CDFA data base whose production might be expected to result in windblown emissions. Pasture lands have been included for the first time with this revision. Orchard and vineyard acreages have been excluded, in part because it is postulated that windblown dust emissions from mature orchards will be relatively minor, and in part because the methodologies for determining the emissions have not been developed.

### Creating the ARBWEQ2 from the WEQ

The agricultural land windblown dust emission estimate is obtained by multiplying the process rate (crop acreage) by an emission factor (tons of suspended PM10 per acre per year). On page 144 et seq. of the EPA-450/3-74-037 document <sup>4</sup> the U.S. EPA established the following modification of the USDA-ARS WEQ:

$$E_s = AIKCL'V'$$

where

$E_s$  = emission factor: suspended particulate fraction of wind erosion losses of tilled fields, tons/acre/year

$A$  = portion of total wind erosion losses that would be measured as suspended particulate, estimated to be .025

$I$  = soil erodibility, tons/acre/year

$K$  = surface roughness factor, dimensionless

$C$  = annual climatic factor, dimensionless

$L'$  = unsheltered field width factor, dimensionless

$V'$  = vegetative cover factor, dimensionless

The soil erodibility (“I”) was initially established for the WEQ for a large, flat, bare field in Kansas. Kansas has relatively high winds, along with hot summers, and low precipitation. The “K”, “C”, “L” and “V” factors serve to adjust the equation for applicability to field conditions that differ from the original Kansas field. The overall approach to calculating emissions used in the WEQ was also used in the ARBWEQ1. However, the WEQ monthly profile was based only on the monthly “C” factor, while the ARBWEQ1 profile was based loosely on statewide erosive energy estimates. The ARBWEQ2 by contrast, while still retaining many of the factors present in the WEQ, is dramatically different in how some of the factors are derived, and has replaced factors and added others, along with adopting a

temporal approach to the calculation that allows the emission estimate to include factors that change from month to month. The rest of this section summarizes the ARBWEQ2 implementation of the WEQ.

The “A” factor has been used in the ARBWEQ2 without modification. In the WEQ, “T” is a function of soil particle diameter, which can be estimated for various soil textural classes from Table A-1 of the above U.S. EPA methodology. For the ARBWEQ2 the soil textural classes were determined by ARB staff from University of California soil maps.<sup>10</sup> For most of the San Joaquin Valley Air Basin (SJV) counties an additional level of detail was included in the ARBWEQ2, by using the NRCS’ State Geographic Data Base (STATSGO) of soil data.<sup>11</sup> The ARBWEQ2 also added a USDA-ARS recommended adjustment for changes to long term erodibility due to irrigation.<sup>12</sup> This affects a property known as cloddiness, and, in this case, refers to the increased tendency for a soil to form stable agglomerations after being exposed to irrigation water. The same USDA-ARS source also provided the methodology implemented in the ARBWEQ2 to estimate the short-term effects of irrigation on erodibility due to surface wetness.

The “K” factor reflects the reduction in wind erosion due to ridges, furrows, and soil clods. The “K” factor is crop specific. The ARBWEQ2 values for “K” were derived from Table A-2 in the above U.S. EPA methodology. The annual climatic factor “C” is based on data that show that erosion varies directly with the wind speed cubed, and as the inverse of the square of surface soil moisture. For the ARBWEQ2, ARB staff improved the input data, as well as the methods associated with developing the county wide averaged annual climatic factor. Monthly climatic factors for the ARBWEQ2 were obtained by modifying the annual “C” factor calculation method. Figure A-5 in the U.S. EPA methodology<sup>4</sup> allows the calculation of the unsheltered field width factor (“L”) from the unsheltered field width (“L”) and the product of erodibility (“T”) and surface roughness (“K”). The values for “L” used in the ARBWEQ2 were derived from Table A-2 in the above U.S. EPA methodology.

The vegetative cover factor “V” is especially problematic for California, and was completely replaced by a series of factors in the ARBWEQ2 (see analysis below). The “V” factor assumes a certain degree of erosion reduction year round based upon postharvest vegetative debris. This factor does not account for barren fields from land preparation, growing canopy cover, or replanting of crops during a single annual cycle. All of these factors are very important in the estimation of windblown agricultural dust emissions in California. Therefore, ARB staff replaced the “V” factor with separate crop canopy cover and postharvest soil cover factors. Although the postharvest replant factor is listed in this report as a partial replacement for the “V” factor, it actually affects the ARBWEQ2 calculation more broadly. The postharvest replant factor is implemented by removing the replanted acreage from the inventory at the time of replanting. Therefore, all of the temporally calculated components will be affected by this adjustment. There were no provisions in the WEQ to adjust for barren regions of planted fields, or field border areas. Bare and border region adjustments have been included in the ARBWEQ2. The following sections provide more detail on some of the more interesting methodology changes between the WEQ (ARBWEQ1) and the ARBWEQ2.

Because current environmental law focuses on PM10 rather than PM, the ARB used a conversion factor of 0.5 in both the ARBWEQ1 and the ARBWEQ2 in order to estimate the PM10 emissions fraction of the windblown agricultural PM emissions. This factor is consistent with studies of emissions from soils in the SJV.<sup>13</sup>

## **Climate-based Improvements in the ARBWEQ2**

### **Annual “C” Factor**

Page 154 of the EPA-450/3-74-037 document<sup>4</sup> includes a definition of the “C” factor which agrees with the method utilized by the United States Department of Agriculture - Natural Resources Conservation Service (NRCS).<sup>14</sup> It incorporates the monthly precipitation effectiveness derived from precipitation and temperature, along with monthly average wind speeds. Garden City, Kansas is assigned

a factor of 1.0 and the “C” factors for all other sites are adjusted from this using the “C” factor calculation. For the ARBWEQ1, ARB staff used NRCS-produced California statewide and county “C” factor contour maps.<sup>15</sup> The data used for producing these contour maps came from a number of sources (see supplemental documentation<sup>8</sup> for reference list). For the ARBWEQ2, the ARB staff produced contour maps using updated California Irrigation Management System (CIMIS) data,<sup>16</sup> that were then grid counted to determine the weighted average “C” factors for the agricultural production land in each county. The CIMIS data were collected using standard methodologies that more closely reflected the conditions encountered by agricultural fields than other climatic data sources.

### **Monthly “C” Factor**

To account for California seasonality, ARB staff devised a method termed the “month-as-a-year” method which produced “C” factors which would apply if the climate for a given month were instead the year round climate. Once normalized, these numbers provided the climate-based temporal profile.

The month-as-a-year method in the ARBWEQ2 produces pronounced curves with small “C” factors (resulting in lower emissions) in the cool, wet and more stagnant periods, and large “C” factors (and higher emissions) in the hot, dry, and windy periods. The method suggested by the U.S. EPA<sup>4</sup> substitutes monthly wind speed for annual wind speed, and yields gentler profiles which are shifted into the cooler and wetter months from the ARBWEQ2 profiles. The USDA-ARS provided ARB staff with erosive wind energy (EWE) profiles that also shifted the emissions into the cooler and wetter months from the ARBWEQ2 profiles.<sup>17</sup> The ARBWEQ1 methodology established an EWE distribution statewide.<sup>1</sup> This resulted in a nearly flat distribution, with very little seasonality. Therefore, of the methods discussed, the ARBWEQ2 month-as-a-year method provides what we believe to be the most realistic seasonal profile. The improvements arising from the use of the month-as-a-year method are due to the fact that it varies temperature, and precipitation inputs, in addition to wind.

While the month-as-a-year method improved the seasonal profile results, it still did not account for all of the factors causing monthly variations in the agricultural windblown dust emissions. Therefore, the ARBWEQ2 further modifies the monthly profile by using the nonclimate-based adjustments to the temporal profile discussed below.

### **Nonclimate-based Improvements in the ARBWEQ2**

Among the nonclimate-based factors that influence windblown agricultural emissions are soil type, soil structure, field geometry, proximity to wind obstacles, crop, soil cover by crop canopy or postharvest vegetative material, irrigation, and replanting of the postharvest fallow land with a different crop. Several of the above factors are particularly applicable to California agriculture, and yet are not included in the standard WEQ (or ARBWEQ1). Many of the nonclimatic corrections incorporated into the ARBWEQ2 to correct for the limitations of the WEQ are temporally-based. These temporally-based factors are all influenced by the crop calendar, and are discussed below. However, the long-term irrigation-based adjustment to erodibility, due to soil cloddiness, is not temporally-based, and is therefore applied for the entire year.<sup>12</sup> The latter change in erodibility varies based on soil type, but, for the ARB inventory, often results in a reduction in emissions for irrigated crops of about one-third.

### **Crop Calendars: Quantifying Temporal Effects**

Factors such as crop canopy cover, postharvest soil cover, irrigation, and replanting to another crop, are temporally-based. Estimating the effects of these factors requires establishing accurate crop calendars to reflect field conditions throughout the year. The planting and harvesting dates are critical components of the crop calendar. Each planting month for a given crop was viewed by ARB staff as a separate maturation class. Since a single planting month’s maturation class may be harvested in several

months, each maturation class was split into plant/harvest date pairs. The plant/harvest date pairs were then assigned based upon a first-in-first-out ordering. The fraction of a plant/harvest date pair that has been planted, but not harvested at any given time, is termed the growing canopy fraction. The growing canopy fraction determines the fraction of the acreage that will have the crop canopy factor applied to its emission calculations. The acreage that is not assigned to the growing canopy fraction is the postharvest/preplant acreage. The postharvest/preplant acreage will have the postharvest soil cover, and replanting to a different crop factors applied when calculating its emissions.

The effect of using plant/harvest date pairs is to blend the temporal emission calculation effects over both the planting and harvesting periods. This approach provides a more realistic estimate of the temporal windblown emissions profile for these periods. All of the monthly factor profile adjustments described below are calculated for each month of the year, for each plant/harvest date pair, for each crop, for each county.

### **Adding a Short-term Irrigation Factor for Wetness**

This adjustment, provided by the USDA-ARS,<sup>12</sup> takes into account the overall soil texture, number of irrigation events, and fraction of wet days. The irrigation factor for months in which irrigations take place will usually result in a reduction in erodibility of less than 20%. This is only an estimate for a typical case during the growing season. When averaged over the year, the overall reduction in erodibility is lower.

### **Replacement Factors to Address Problems with the “V” Vegetative Soil Cover Factor**

There are many problems with the WEQ’s “V” factor. For example, the “V” factor is applied to the acreage year round, even during the growing season. This ignores the effect of canopy cover during the growing season, as well as the effects of disk-down and other land preparation operations on postharvest vegetative soil cover. In addition, the WEQ was derived based on agricultural practices typical of the Midwestern United States. In California, crops such as alfalfa have canopy cover for nearly the entire year. There is also a large amount of acreage in California that is used for more than one crop per year, and there was no provision in the “V” factor for estimating the effects on emissions of this replanting. Whether the land is to be immediately replanted to a different crop, or is going to remain fallow until the next planting of the same crop, it is common practice in California to disk under the harvested crop within a month or two of harvest. The “V” factor for the most part assumes that the postharvest debris remains undisturbed. ARB staff replaced the “V” factor in the ARBWEQ2 with the three adjustments discussed below to approximate the effects on windblown agricultural PM emissions of: 1. crop canopy cover during the growing season; 2. changes to postharvest soil cover; 3. postharvest planting of a different crop on the harvested acreage.

Crop canopy cover is the fraction of ground covered by crop canopy. USDA-ARS staff provided the ARB with methodology from the RWEQ for estimating the effects of crop canopy cover on windblown dust emissions.<sup>5</sup> The soil loss ratio for canopy coverage (SLRcc) is the factor which is multiplied by the erodibility to adjust the erodibility for canopy cover. The SLRcc is defined as the ratio of the soil loss for a soil of a given canopy cover divided by the soil loss from bare soil. The greater the canopy cover, the smaller the SLRcc, and the greater the reduction in erodibility. The SLRcc curve exhibits major differences in the erodibility reduction for the range of zero to 30 percent canopy cover (typically achieved within a few months after planting). Thereafter, reductions occur much more slowly, and eventually the curve flattens out. This results in a rapid decrease in emissions in the first few months following planting, until the emissions are only a very small fraction of the bare soil emissions. Postharvest soil cover is the fraction of ground covered by vegetative debris. USDA-ARS staff provided the ARB with methodology from the RWEQ for estimating the effects of postharvest soil cover on windblown dust emissions.<sup>5</sup> The postharvest soil loss ratio for soil coverage (SLRsc) is defined as the

ratio of the soil loss for a soil of a given postharvest soil cover divided by the soil loss from bare soil. The greater the postharvest soil cover, the smaller the SLRsc, and the greater the reduction in erodibility.

As discussed above, the “V” factor does not include any adjustments for harvested acreages that are quickly replanted to a different crop. This multiple cropping is very common in California, and has been accounted for by removing from the inventory calculation the fraction of the harvested acreage that is replanted, at the estimated time of replanting, causing a reduction in the emissions estimate.

### **Bare and Border Soil Adjustments**

Barren cultivated areas could be due to uneven ground (e.g., water accumulation), uneven irrigation, pest damage, soil salinity, etc. Many field border areas are relatively unprotected, and prone to wind erosion. The ARB staff established approximate fractions of cultivated acreage that would be barren and border areas, respectively. These barren and border acreage adjustments result in emission increases disproportionate to the acreage involved. The reason that the bare acreage-based increase is so large is that the bare acreage does not have either a crop canopy or postharvest soil cover factor applied. The same reasons apply to the border adjustment, but the border region is also assumed to be nonirrigated. Therefore, neither the irrigation factor (wetness) nor the long-term irrigation adjustment to erodibility (cloddiness) are applied. No border adjustment was applied to the pasture acreage, since pasture areas frequently lack a barren border.

### **Geographic Information System Mapping of ARBWEQ2 Calculated Emissions**

In recent years geographic information systems (GIS) have emerged as powerful tools for visualizing localized emission estimates from many different source types. Those emission calculation methodologies, such as the ARBWEQ2, which include location specific data and adjustment factors, are especially amenable to the layered data approach allowed by GIS. The basic approach used by ARB staff to establish coverages and produce graphic output from the ARBWEQ2 is similar to that used by ARB staff earlier for agricultural tillage emission estimates.<sup>18</sup>

## **RESULTS**

### **Annual Emissions Comparisons**

Figure 1 shows the ratio of the ARBWEQ2 to the ARBWEQ1 nonpasture emissions for six representative California counties. This figure only shows nonpasture emissions, since the ARBWEQ2 was the first inventory revision which included pasture emissions. Overall, there was a dramatic drop in the annual emissions estimate of approximately 80% statewide. The amounts of reductions in the emissions estimates did vary significantly between counties. The acreage changes between the ARBWEQ1 and the ARBWEQ2, although in some cases significant, were not responsible for the dramatic decreases in the emissions estimates experienced by most counties. The large reductions in annual emissions estimates were due predominantly to the effects of both the annual and the month-based adjustments introduced in the ARBWEQ2.

### **Temporal Profile Comparisons**

Although annual-based adjustments, such as adjustments to the overall soil erodibility, the long-term erodibility adjustment due to irrigation (cloddiness), and changes to the annual “C” factor caused large changes for some counties; much of the decrease in the annual emission estimate between the ARBWEQ1 and the ARBWEQ2, reflected in Figure 1, was actually due to the temporal, or monthly profile-based adjustments. Several possible temporal profiles are shown in figures 2 and 3 for Fresno

County nonpasture and pasture windblown emissions, respectively. It is valid to compare both the nonpasture-based and pasture-based ARBWEQ2 profiles with the same profiles in figures 2 and 3, because, unlike the ARBWEQ2, the other profiles are not crop specific. For the ARBWEQ1, the temporal profile was based on an estimated statewide erosive wind energy (EWE) profile. This profile was very flat, and did not adequately reflect the seasonality present in most California counties. The U.S. EPA and USDA-EWE profiles, discussed above in the methods section, were both shifted into the cooler and wetter months (January through March), and were, therefore, also not satisfactory. The profile, implemented in the ARBWEQ2 now includes wind, precipitation and temperature climatic effects, along with the addition of the effects of crop canopy, postharvest soil cover, postharvest replanting to a different crop, and irrigation. In addition, the inclusion of bare ground and field border effects also adjusted the profile in the ARBWEQ2. The ARBWEQ2 profile better reflects the California seasonality, as well as the nonclimatic influences that cause monthly emissions to vary.

The ARBWEQ2 nonpasture temporal profiles for Fresno and San Joaquin counties are compared in Figure 4. The Fresno profile is low in the wet months of November through March, and then jumps dramatically in April due to the combination of the planting of Cotton (which is by far the largest crop in Fresno County), lower precipitation, and increased wind. The net result is that large acreages of freshly planted land, with little ground cover, and lower soil moisture are exposed to higher wind speeds. However, the Fresno profile then drops off sharply due mostly to the maturation of the cotton crop (as well as other crops planted in the same time period) increasing the ground cover. There is a small peak again in late summer to early fall, due mostly to crop harvesting decreasing the ground cover, after which the emissions drop off primarily due to a combination of increasing precipitation, decreasing temperature and lower wind speeds. The San Joaquin County profile is similar for much of the year, with the exception of the lack of the large Spring peak. The Spring peak is missing because San Joaquin County is not dominated by a single crop, like cotton, with a relatively narrow planting window.

The ARBWEQ2 pasture temporal profiles for Fresno and San Joaquin counties, shown in Figure 5, follow basically the same pattern as the cotton dominated Fresno County nonpasture profile, because they reflect a single crop. However, there is a strong Fall peak as well, because the field preparation and planting for pasture are split between the late Spring and early Fall months.

## **Examining Contributions to the Estimate Reduction, and Validating the Estimate**

With so many new features in the ARBWEQ2, it is important to understand how each change has affected the emissions estimates. The annual “C” factor and STATSGO-based erodibility changes were significant in some cases, and were responsible for some, but not the major portion of the emissions decreases between the ARBWEQ1 and the ARBWEQ2. The short-term irrigation factor (wetness) may reduce the emissions by 10% to 20% during the months when the “C” factor profile peaks. Emissions are also reduced due to the postharvest soil cover, and the replant factor, but these are occurring during periods when the “C” factor profile is lower, and so have less of an effect. For most counties, the largest portions of the emission reductions between the ARBWEQ1 and the ARBWEQ2 estimates are due to the long term irrigation factor (cloddiness) adjustments (which in some cases decrease the emissions estimate by one-third), and the combination of the “C” factor profile and the crop canopy cover. The reductions due to the combination of the “C” factor profile and the crop canopy cover are large for many important crops, because the large monthly climatic factors in the summer shift the emissions into the summer months, when many crop canopy covers are at their maximum.

Existing air pollution monitoring source apportionment data support the decrease in the annual windblown agricultural PM10 estimate from the ARBWEQ1 to the ARBWEQ2, as well as supporting the ARBWEQ2 temporal profile over the ARBWEQ1 profile and other alternative profiles discussed here.<sup>19,20,21,22</sup>

## GIS Map

The GIS-produced map in Figure 6, shows how the estimated emissions are distributed throughout the SJV. The map reflects the amount of emissions coming from each of the 4 km<sup>2</sup> grid cells. This is not the same as the emissions per cultivated acre, which is the value actually used as the emission factor. Nevertheless, the map does reflect well the expected distribution of windblown agricultural emissions throughout the SJV. The higher emission areas in Kings County and the western portion of Fresno County reflect the region in the SJV with the highest climatic factors, large cultivated to uncultivated land ratios, and an overall intermediate crop emissivity. The higher emissivity crops tend to be those that have lower soil cover during the times when the climatic factor is high. Shorter growing season crops, such as lettuce and cantaloupe, will have more frequent periods of low canopy cover, which will often coincide with periods of the year having higher climatic factors. If not for Cotton's long growing season, when canopy cover is maintained for a long period, the emission levels in the western Fresno County and Kings County would be much higher. The relatively low emissions in San Joaquin County are due in large part both to the crop mix, and the lower annual climatic factor.

## CONCLUSIONS

The ARBWEQ2 is much more California-specific than the ARBWEQ1, which was for the most part a direct implementation of the U.S. EPA's WEQ. Currently available emission source apportionment data indicate that the ARBWEQ2 is a major improvement with respect to both the annual emissions estimate and the monthly emissions profile.

## ACKNOWLEDGMENTS

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## DISCLAIMER

This report has been reviewed by the staff of the California Air Resources Board and approved for release. Approval does not signify that the contents necessarily reflect the views and policies of the Air Resources Board. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

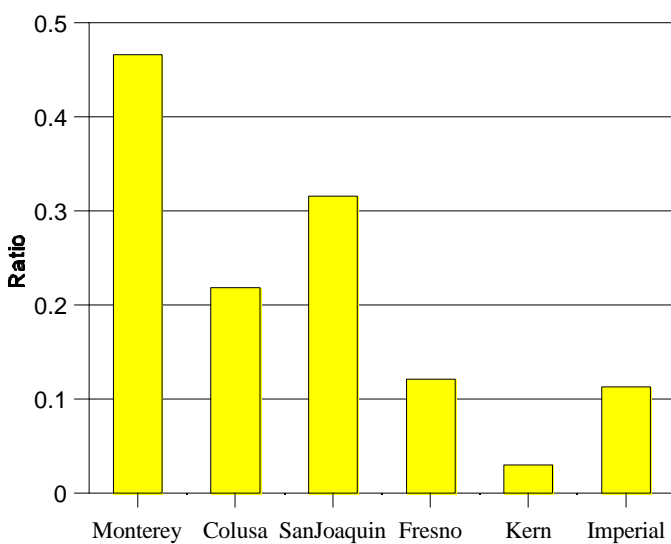
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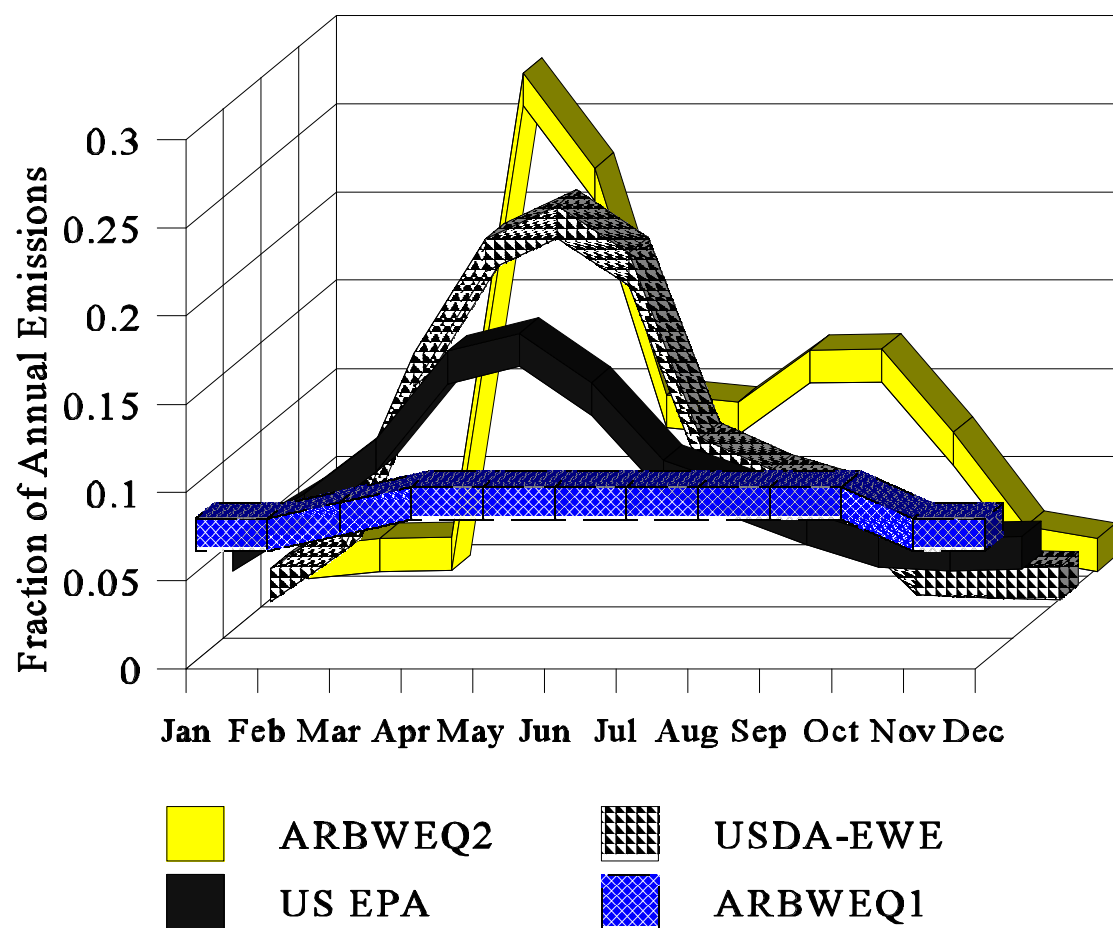


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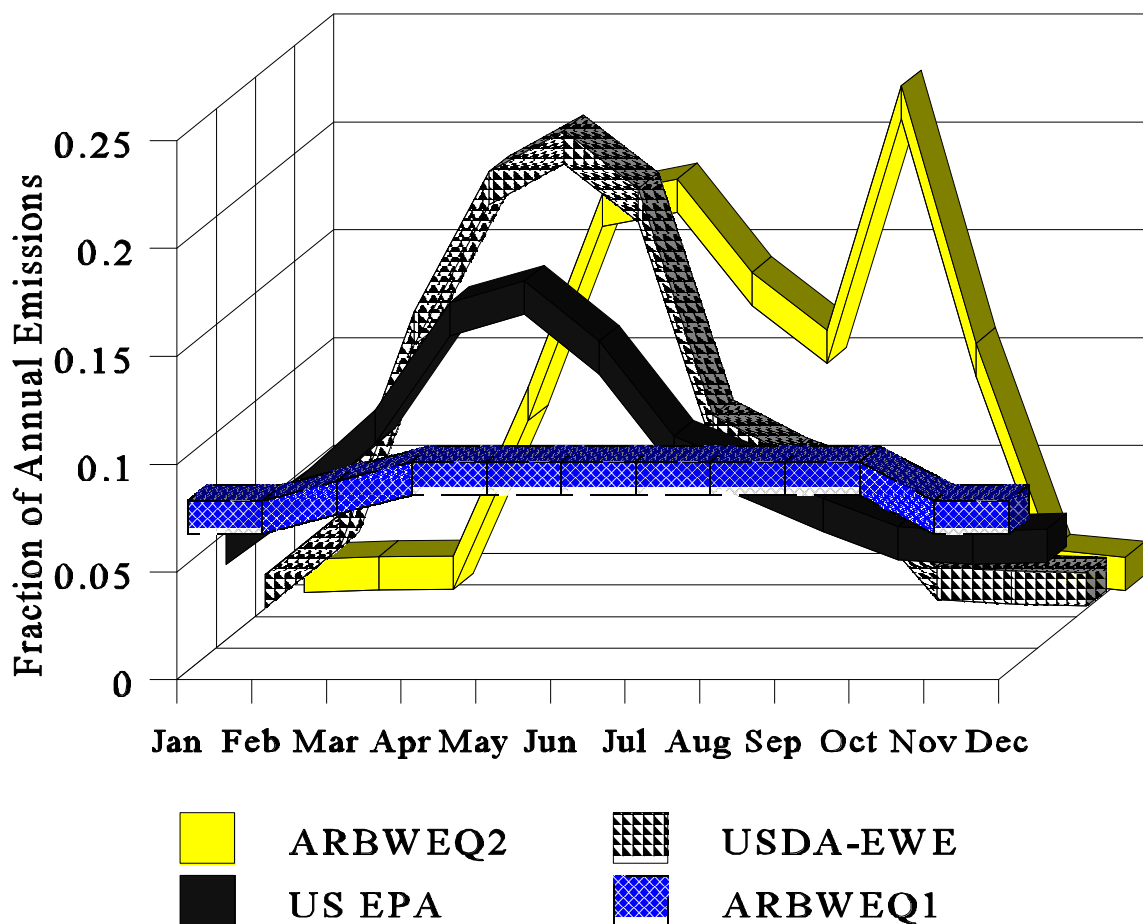
**Figure 1:** Ratio of nonpasture emissions: ARBWEQ2/ARBWEQ1.



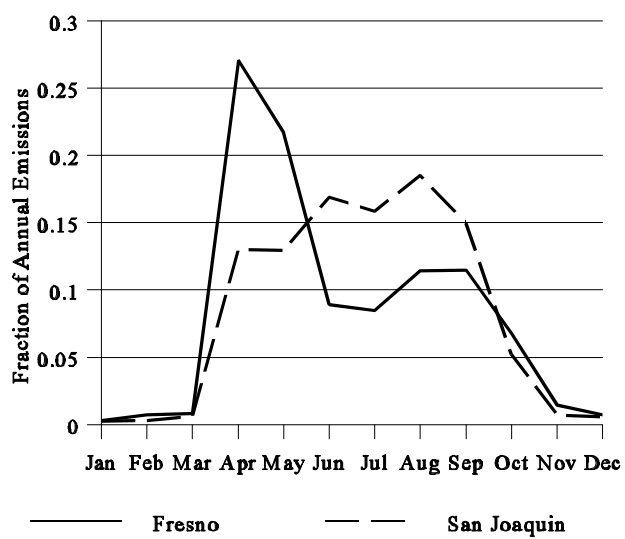
**Figure 2:** Fresno County nonpasture agricultural windblown emission profiles.



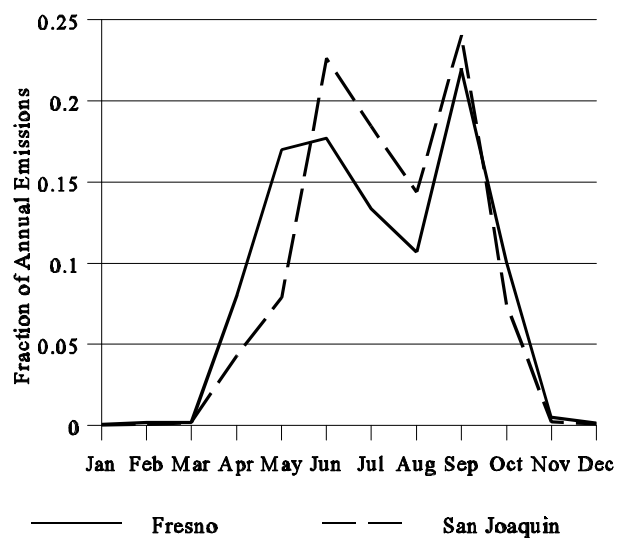
**Figure 3.** Fresno County pasture windblown emission profiles.

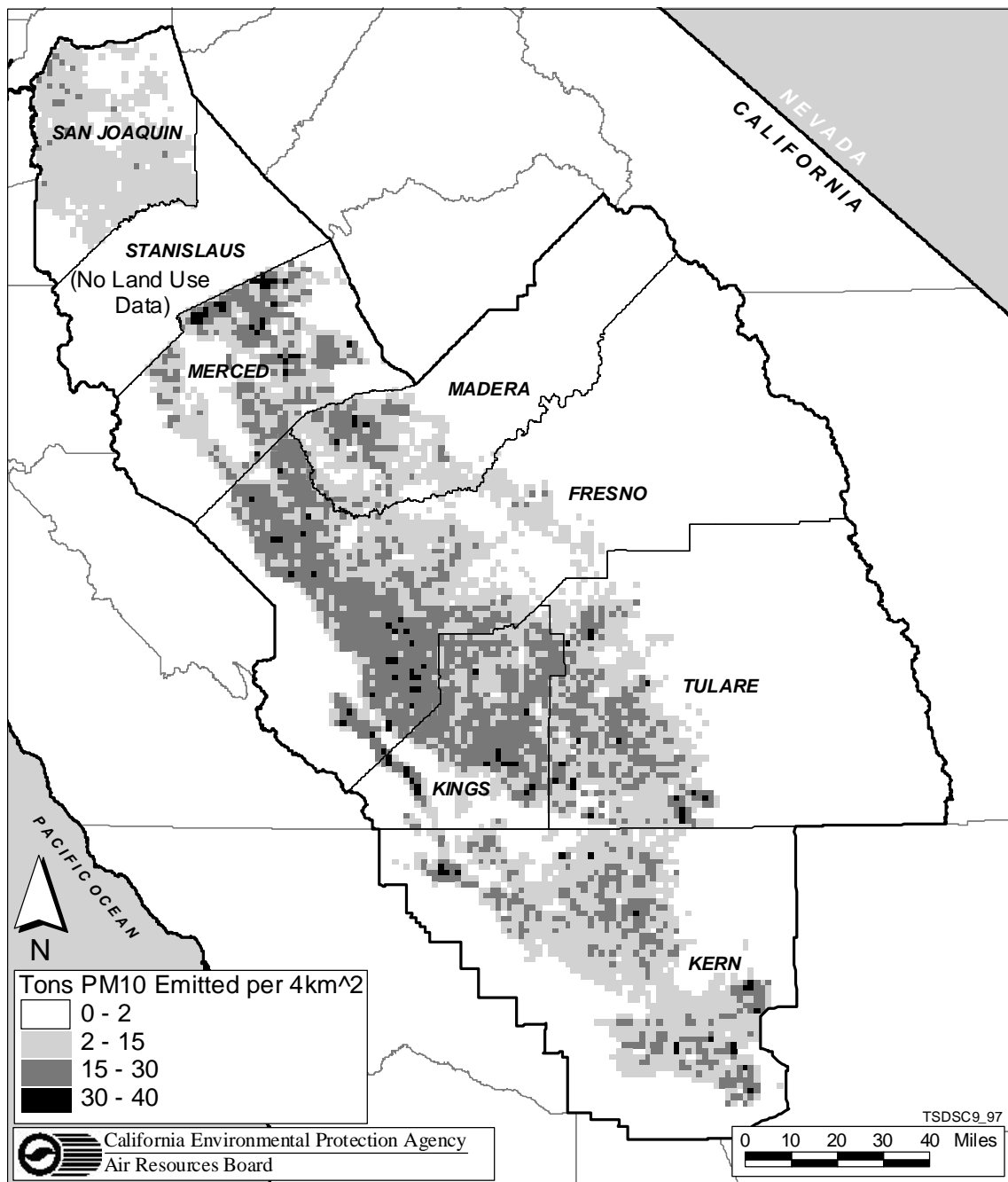


**Figure 4.** Nonpasture emission profiles.



**Figure 5.** Pasture emission profiles.





**Figure 6:** Annual PM10 emissions distribution in the SJV using the ARBWEQ2.

*Keywords: Agricultural windblown dust, California Air Resources Board, emissions inventory, PM10, wind erosion equation, WEQ.*